ECCO2: High Resolution Global Ocean and Sea Ice Data Synthesis

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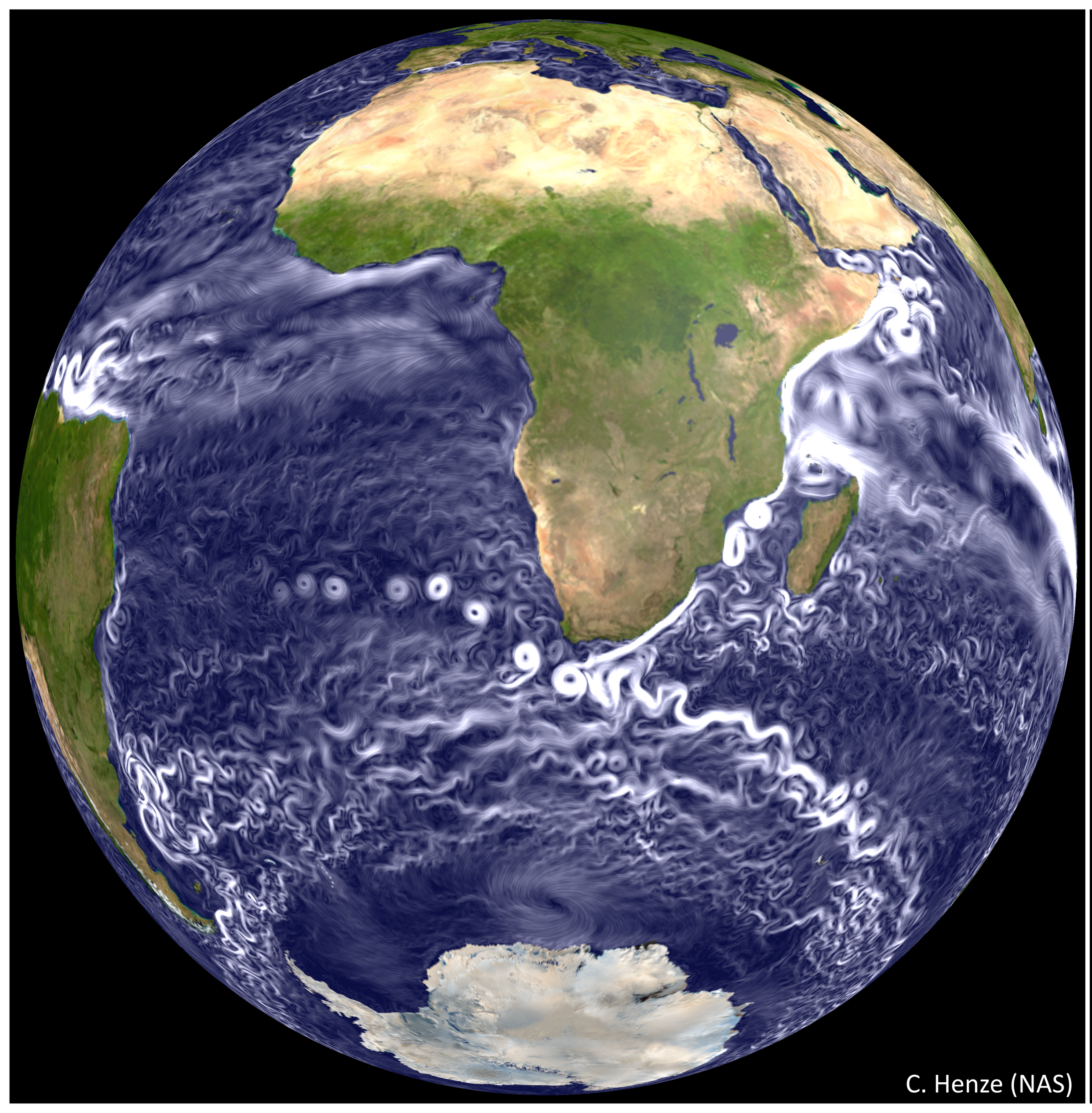
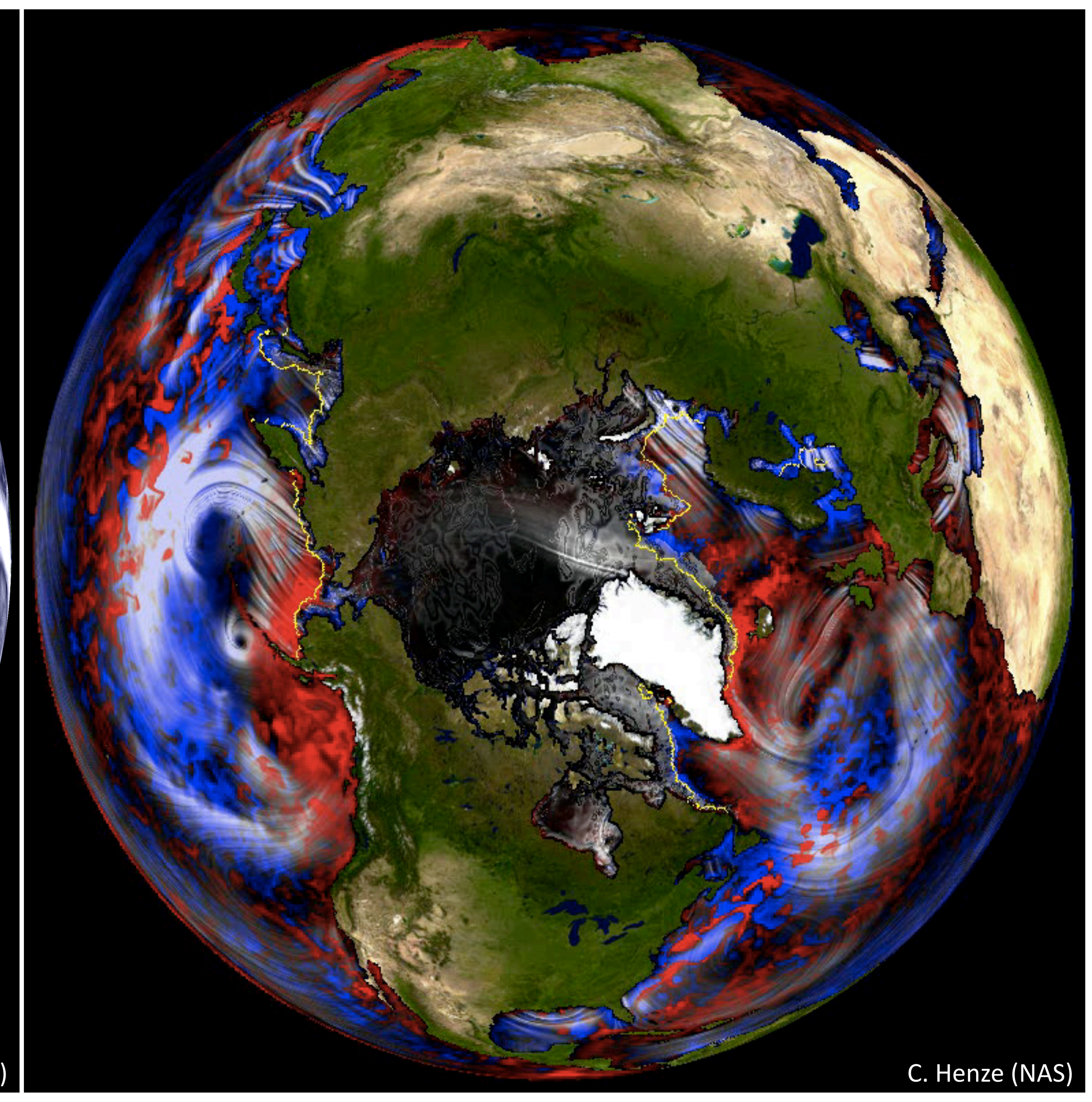
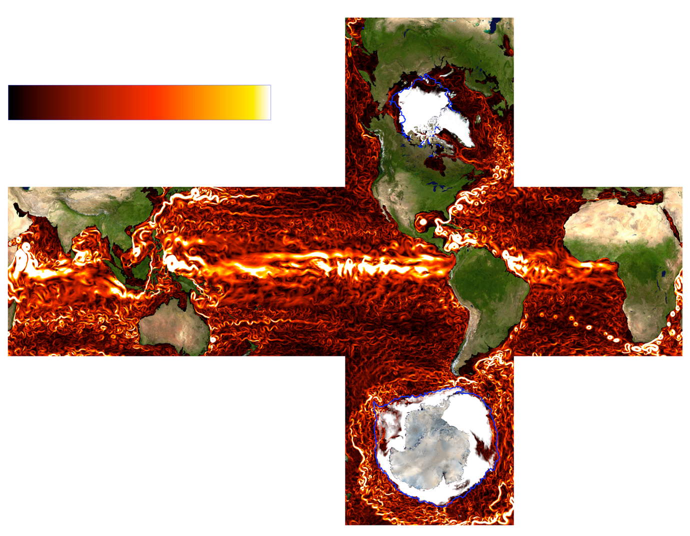
Ocean State Estimation in the presence of eddies and ice

The Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) project aims to produce a best-possible, time-evolving synthesis of most available ocean and sea-ice data at a resolution that admits ocean eddies. ECCO2 analyses are obtained via least squares fit of a global, full-depth-ocean, and sea-ice configuration of the Massachusetts Institute of Technology general circulation model (MITgcm) to the available satellite and in-situ data. What sets apart ECCO2 analyses from operational high-resolution ocean data assimilation products is their physical consistency; in particular, the analyses do not contain discontinuities when and where data are ingested. ECCO2 data syntheses are being used to quantify the role of the oceans in the global carbon cycle, to understand the recent evolution of the polar oceans, to monitor time-evolving term balances within and between different components of the Earth system, and for many other science applications.

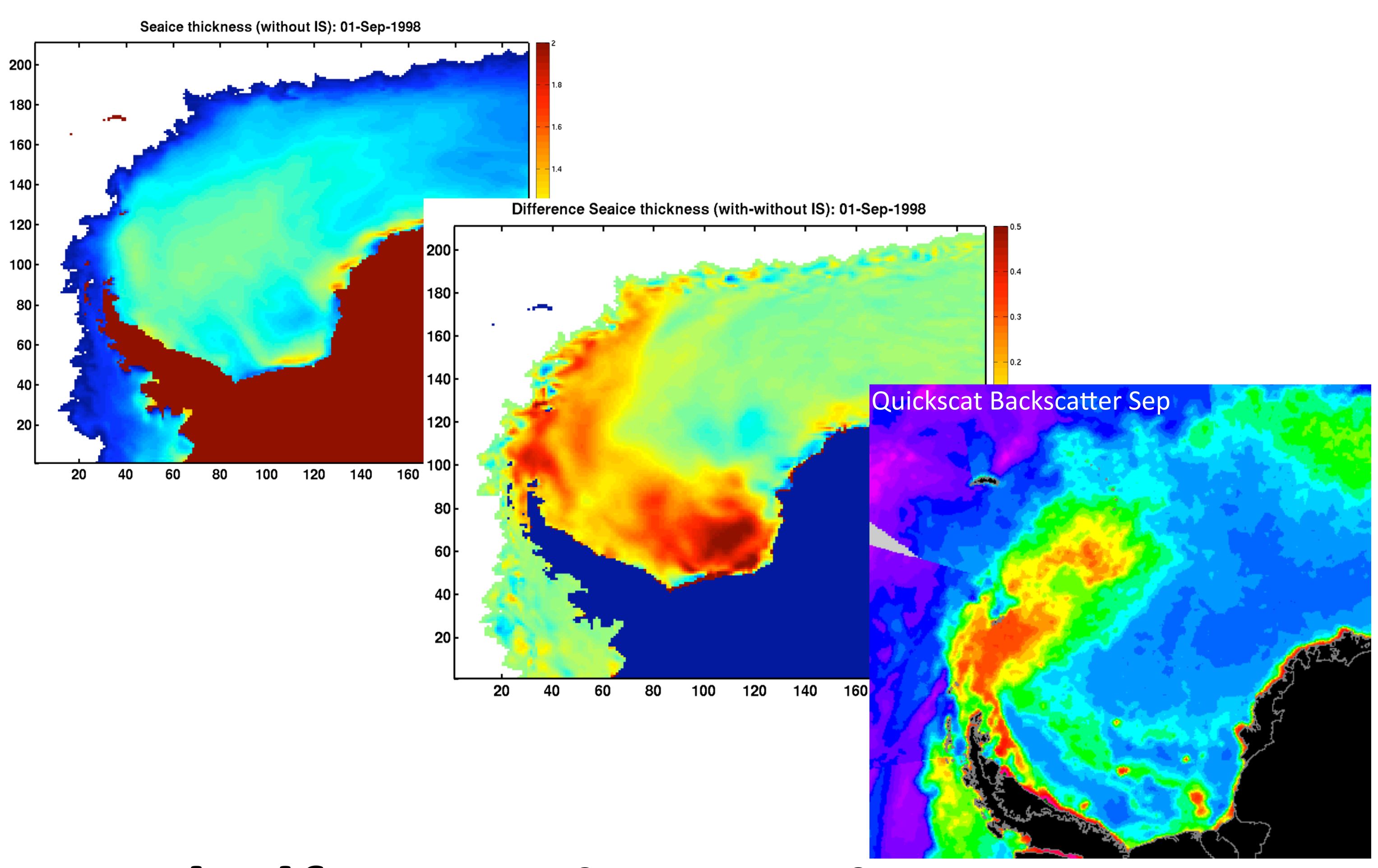


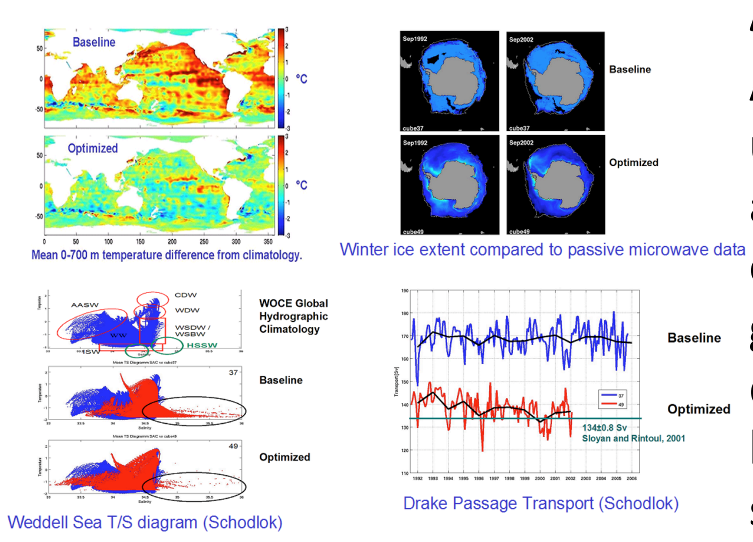




Global ocean and sea ice model

The computational demands of rigorous ocean state estimation are enormous. Therefore, a necessary condition is an efficient global ocean and sea ice model and significant computational resources. A first, global ECCO2 solution was obtained on a cubed-sphere coupled ocean and sea-ice configuration of the MITgcm with mean horizontal grid spacing of 18 km and 50 vertical levels.



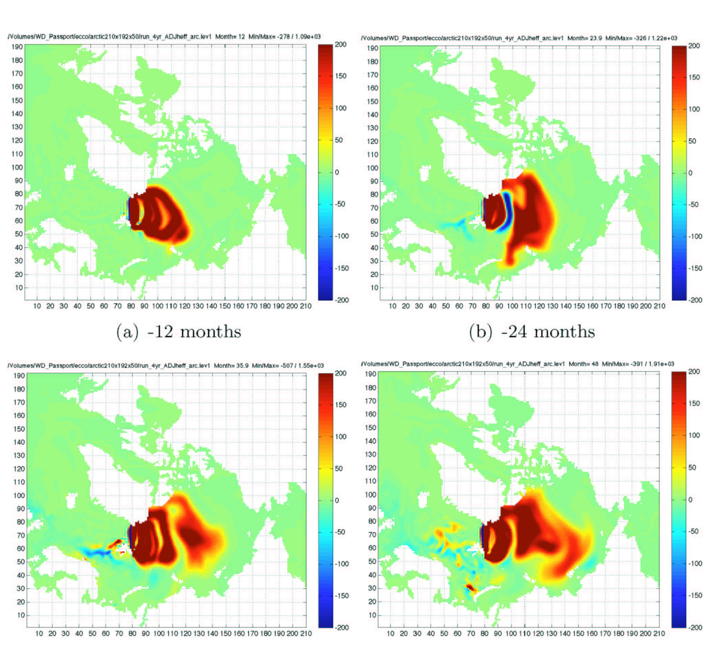


A first ECCO2 optimization

A first ECCO2 synthesis for the 1992-2002 period has been obtained using a Green's Function approach to estimate initial temperature and salinity conditions, surface boundary conditions, and several empirical model parameters. Data constraints include altimetry, gravity, drifter, hydrographic, and sea-ice data. The figure to the left displays some of the large-scale biases that were present in the baseline integration and the equivalent fields from the optimized solution, demonstrating significant improvements of the optimized solution relative to the baseline integration.

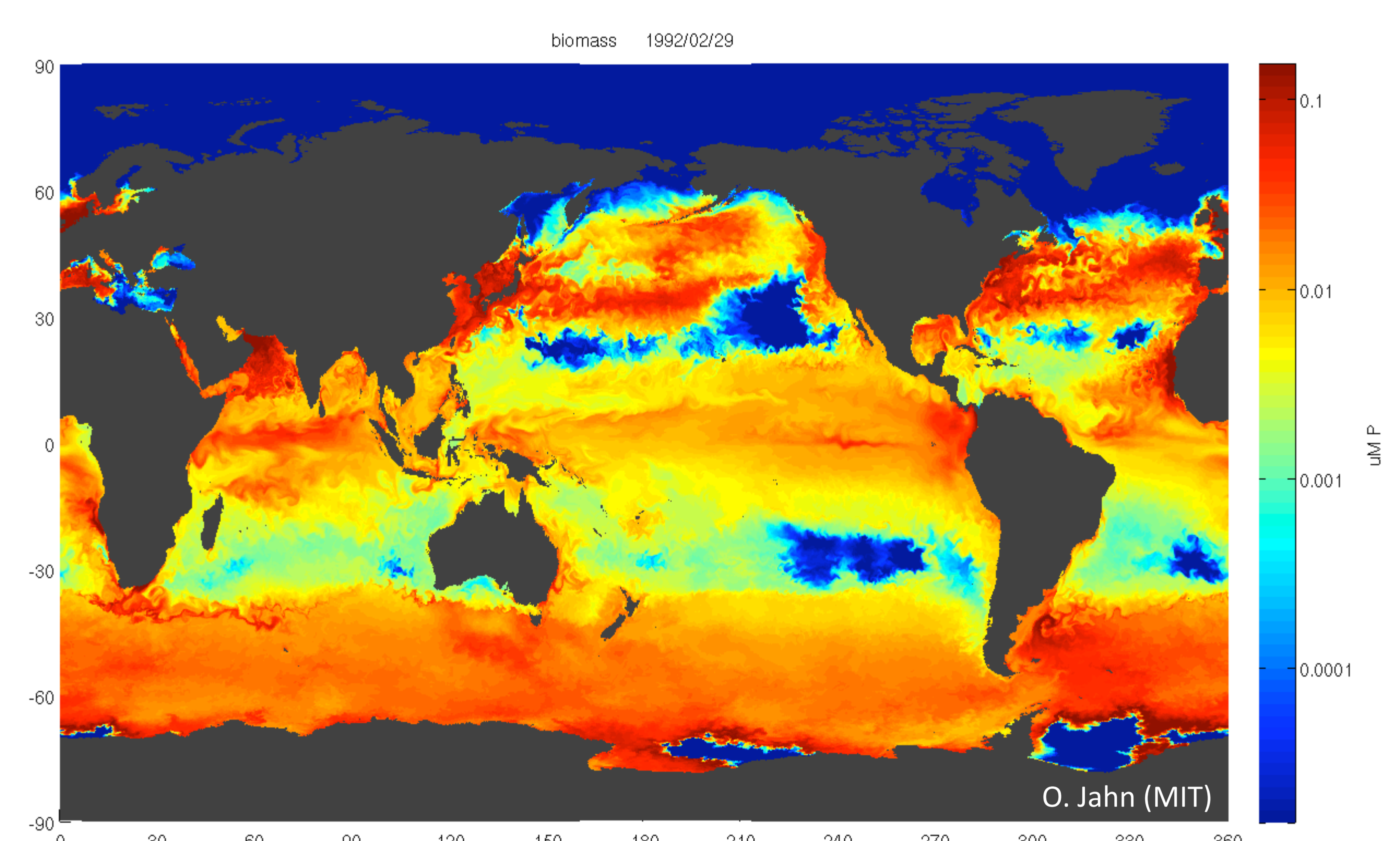
Ice shelf ocean interactions

Work is underway to improve the representation of ice shelf ocean interactions in the ECCO2 solutions. For example, M. Schodlok is studying the impact of ice shelf cavity processes on sea ice (see Figure above) and on deep and intermediate water formation.



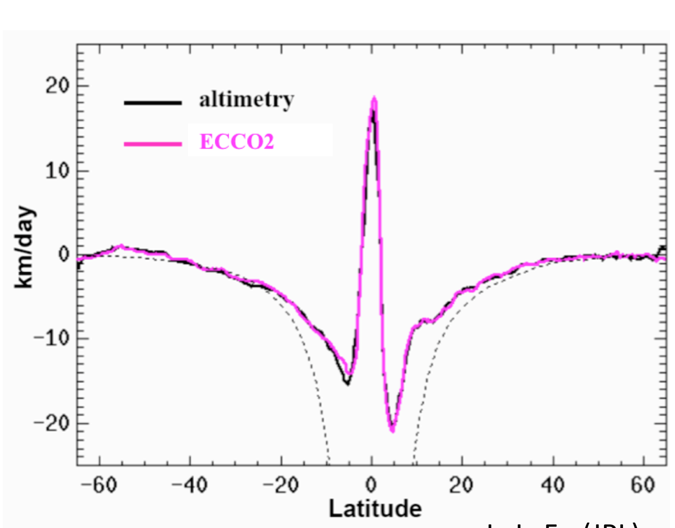
Adjoint ocean and sea ice modeling

In parallel with the Green's function optimization, work is underway towards adjoint-method optimization on the same grid. One objective of the MITgcm ocean and sea-ice model development effort has been to provide the capability for automatic generation of the adjoint model from up-to-date versions of the MITgcm. The coupled ocean/sea-ice adjoint now yields stable and physically meaningful adjoint sensitivities or Lagrange multipliers. By way of example, the figure to the left depicts sensitivity maps of sea-ice export through Fram Strait during December 1995 to changes in ice thickness at any point in the domain 1, 2, 3, and 4 years prior.



Self-assembling marine ecosystem

ECCO2 results are being used to supply boundary conditions for regional studies and to drive biogeochemical, geodetic, acoustic, and electromagnetic models. For example, O. Jahn used ECCO2 results to drive a self-assembling marine ecosystem, a shown in the figure above.

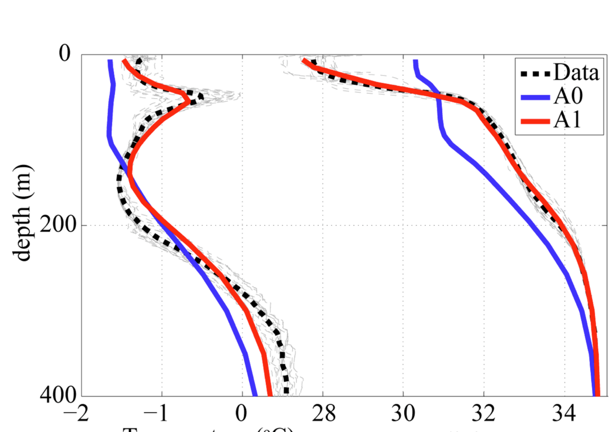


Eddy-mean flow interactions

A first set of early science applications concerns the impact of mesoscale eddies on large-scale ocean circulation and its variability. For example, L.-L. Fu used correlation between successive maps of sea-surface height to estimate eddy propagation characteristics. The figure to the left shows the zonally averaged zonal component of the eddy propagation velocity as a function of latitude. Similarities and differences between results from observed and simulated sea-surface height variability improve understanding of model and data errors and of the underlying physical processes.

Available ECCO2 products

ECCO2 modeling and estimation tools and results are freely available to the scientific community. Model configurations and parameterizations are available at http://mitgcm.org. Automatic differentiation tools are available at http://www-unix.mcs.anl.gov/OpenAD. Finally, modeling and estimation results are available at http://ecco2.org



Sea ice ocean interactions

A second set of early science applications concerns the study of ice-ocean interactions. For example, A. Nguyen investigated the reasons why coupled ocean and sea ice models in the Arctic tend to misrepresent the upper ocean stratification. To address this problem, a new sub-grid-scale parameterization of salt plumes was developed, resulting in a considerably more realistic representation of the cold halocline in the Arctic Ocean as depicted in figure to left.

Acknowledgments

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